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AUTHOR McLean, Lois; And Others
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ABSTRACT

One of the important components of the elaboration theory (Reigeluth, 1979) is the synthesizer, which provides information to relate and integrate a set of concepts and which can appear in different formats. This study investigated the effectiveness of three formats of post-instruction synthesizer on student recall of definitions of concepts and recall of relationships among those concepts. The subjects were 47 high school students who were randomly assigned to five groups: (1) no synthesizer (instruction only); (2) visual synthesizer (tree-chart diagram); (3) verbal synthesizer (written prose); (4) visual plus verbal synthesizer; and (5) control (posttest only). The four treatment groups simultaneously viewed a general-to-detailed slide-tape presentation on microcomputer system parts. A 41-item, short-answer posttest was administered to the no-synthesizer group immediately and to the other three experimental groups following brief study of their assigned synthesizers. Although no significant differences were found between the treatment groups on remembering definitions, the diagram synthesizer group was significantly better at remembering the relationships than the verbal and no-synthesis groups, and the diagram plus verbal synthesis group was significantly better than the no-synthesis group. Contrary to the three hypotheses tested, these results suggest that instruction for parts-conceptual relationships should use a visual-only synthesizer format. This report includes examples of different synthesizers as well as five references. (Author/RP)

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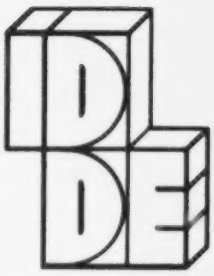

INSTRUCTIONAL DESIGN, DEVELOPMENT, AND EVALUATION

WORKING PAPERS

THE EFFECTS OF FORMAT
OF SYNTHESIZER ON CONCEPTUAL LEARNING

by

Lois McLean
N. Kai Yeh
Charles M. Reigeluth

IDD&E Working Paper No. 13
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Charles M. Reigeluth, Editor
Sheila Thompson, Production Editor
330 Huntington Hall
Syracuse University
Syracuse, NY 13210

ABSTRACT

The effectiveness of three formats of post-instruction synthesizer on student recall of definitions of concepts and recall of relationships among those concepts was studied. Forty-seven high school students were randomly assigned to one of five groups: (1) no synthesizer (instruction only); (2) visual synthesizer (tree-chart diagram); (3) verbal synthesizer (written prose); (4) visual+verbal synthesizer; and (5) control (post-test only). The four treatment groups simultaneously viewed a general-to-detailed slide-tape presentation on microcomputer system parts. A 41-item, short-answer post-test was administered to the no-synthesizer group immediately and to the other three experimental groups following their brief study of their assigned synthesizers. No significance between the treatment groups on remembering definitions was found. However, on remembering the relationships, the diagram synthesizer was significantly better than the verbal and no synthesis, while the diagram+verbal synthesis was only significantly better than no synthesis. Results indicate that instruction for parts-conceptual relationships should use a visual-only synthesizer format.

One of the important strategy components in the elaboration theory (Reigeluth, 1979) is the synthesizer. A synthesizer is comprised, in teaching concepts, of information to relate and integrate a set of concepts and can appear in different formats, for example as a verbal statement or a tree-chart diagram (Reigeluth & Stein, 1983). There have been, however, no research studies which have compared the effectiveness of the various formats of synthesizers.

According to the elaboration theory, instruction is hypothesized to be most effective when presented in a general-to-detailed sequence; and a synthesizer should show relationships, usually parts or kinds for concepts (Reigeluth & Stein, 1983). Synthesizers have several functions:

1. To enforce a deeper understanding of the individual concepts, through comparison and contrast;
2. To increase the meaningfulness and motivational effect of those concepts, by placing them in the larger context; and
3. To facilitate retention, by providing additional links among the new concepts and between the new concepts and a learner's relevant prior knowledge.

Relatedly, Reigeluth and Garfield (1983) have identified two types of synthesizers. One is an internal synthesizer, which shows relationships among the new concepts in a lesson. The other is a within-set synthesizer, which functions both horizontally, to show relationships among concepts in a set of lessons at a given level of elaboration, and vertically to show relationships between those concepts and the more general, inclusive context which contains them.

In his discussion of the elaboration theory, Reigeluth (1979) mentions that the prior theories of Ausubel, Bruner, and Norman have not been explicit in prescribing instructional components. The elaboration theory, in contrast, is a prescriptive theory, but one which has little empirical support for the specific teaching methods it prescribes. The theory does suggest that the effectiveness of synthesizers will be most evident for large chunks of instruction, because of the capability of the human mind to compensate for certain amounts of information even when instruction is poorly designed (Reigeluth, 1979).

Although two studies (Frey & Reigeluth, 1981; Carson & Reigeluth, 1983) have used tree-chart diagrams as synthesizers, research has not yet identified or even addressed the specific format for synthesizers which might be most effective in teaching conceptual structures in any grade level or content area. There is a need to further define synthesizers in terms of what they should include and "look like."

As part of a research study, Frey and Reigeluth (1981) investigated the effect of the position of a within-set, tree-chart diagram

effective at the beginning, in a detailed-to-general sequence, and at the end in a general-to-detailed sequence. The study, however, used a very small sample of only 4-5 students per treatment group, and the purpose of the synthesizer was not presented to the learners and may therefore have been overlooked by some students.

Extending the above study, Carson and Reigeluth (1983) used a set of slides concerning hardware parts of the microcomputer, with 128 eighth grade students. The synthesizer, again, was a within-set tree-chart for all treatment groups but was prefaced with a verbal introduction before learners used it. Carson and Reigeluth (1983) found that having the synthesizer at the end of a lesson was better than at the beginning, regardless of sequence, and having no synthesizer was better than having it at the beginning. Carson and Reigeluth (1983) suggested that the number of concepts (19) may have been too large for a single lesson, and that eighth graders may not be ready to comprehend a tree-chart synthesizer with so many concepts. It is also possible that students may need alternate representations of a synthesizer, or that a specific format of synthesizer may be more effective for specific groups.

The present study was therefore designed to extend the study by Carson and Reigeluth (1983), in order to specifically examine the effectiveness of three formats of synthesizers:

1. visual, in tree-chart diagram form (diagram synthesizer);
2. verbal, in prose form (verbal synthesizer); and
3. visual and verbal in combination (diagram+verbal synthesizer).

Purposes of this study are to:

1. contribute to making the elaboration theory more specific and prescriptive;
2. help supplement the limited research on formats of synthesizers and synthesizers effectiveness generally;
3. help clarify results of previous studies which have occasionally been contradictory; and
4. study synthesizers in a different form than that used in previous studies, which have used tree-charts exclusively.

This study will add to existing knowledge, focusing on specific formats of synthesizers, by trying to determine if the format or representation of the synthesizer is significant. The format of synthesizer that is most effective may depend on such variables as content type, and student characteristics such as age, reading level, and cognitive style. Prior experience in working with charts may also be influential. If initial research indicates differences, later studies could specifically address these issues.

The independent variables in this study are diagram format and verbal format of synthesizer. The dependent variables are student recall of definitions of concepts and recall of relationships among those concepts.

The hypotheses are that, in general-to-detailed instruction using a within-set synthesizer provided at the end of the instruction,

1. There will be no significant differences on recall of definitions or relationships when either a diagram or verbal synthesizer is used (diagram = verbal);
2. Recall of relationships will be better when a combined diagram+verbal synthesizer is used than when either a verbal or a diagram synthesizer is used alone (diagram+verbal > diagram = verbal); and
3. Recall of relationships will be better with a diagram, verbal, or diagram+verbal synthesizer than with no synthesizer in the instruction (diagram, verbal, diagram+verbal > no synthesis).

Methods

Students

The selection of students was based on the recommendation of the Liverpool (New York) School District assistant superintendent for instruction and the permission of the instructor, following a request to the district for a group of students of mixed or average ability who had had no prior formal instruction in microcomputer usage or computer literacy.

A total of 47 students in two classes of general psychology and one of social studies at Liverpool High School taught by the same instructor were used for the study. Students included 13 tenth, 12 eleventh and 22 twelfth grade students, who represented average ability level students, according to the instructor.

To avoid confusion and loss of time during the time periods allowed for each class of students, which ranged from 48-54 minutes, random assignment of students to the treatment and control groups was realized in advance by:

1. numbering the groups one through five, and
2. preparing random number cards (1-5), handed to students at the time of the administration of the experiment.

The numbered cards were prepared through use of the PROC PLAN procedure in the SAS computer program. By defining n/5 groups (where n is the total number of students in each class), the SAS program generated nested numbers 1-5 randomly for each group of 5 students, and the cards were then handed out in that order.

Research Design

The experimental design was a posttest-only control group design. The statistical design was a 2x2 factorial design. The two factors were

diagram synthesizer and verbal synthesizer, each with two levels: absence and presence (see Figure 1).

Insert Figure 1 about here

Instructional Task and Materials

The instructional task required students to view a slide-tape to learn the parts of a microcomputer system. The instructional material was a general-to-detailed slide-tape presentation on the major parts of a microcomputer system. The slides were primarily color photographs of real objects, which were synchronized with an audiotape narration. A few abstract concepts, such as the function of the microprocessor and the meaning of RAM and ROM, were presented through printed words on the slides. A generality-example-practice micro strategy was used. Figure 2 shows an excerpt from the script of the slide-tape, and Figure 3 lists all the concepts that were taught.

Insert Figures 2 and 3 about here

The instruction primarily represented a parts structure, e.g. hardware consisting of the computer unit and peripherals. However, due to the complexity of a microcomputer system, a few concepts did branch into kinds relationships, e.g. the four kinds of input/output devices and the three kinds of software (see Input/Output Ports and Software in Figure 3).

The 16-minute slide-tape was sequenced so that it first introduced the microcomputer system, mentioned the two major parts of hardware and software, but focused first on parts of the hardware before explaining software (see Figure 3). Students in all four treatment groups viewed the same slide-tape together.

Treatments

The four experimental treatments were: 1) no synthesis (or instruction only), 2) diagram synthesizer, 3) verbal synthesizer, and 4) diagram+verbal synthesizer (see Figure 1). A fifth group, the control group, received the posttest booklet only as a pretest without either instruction or synthesis. All synthesizers were in print form on 8.5x11 inch paper, photocopied from typewriter-produced originals. The two types of synthesizers were on separate sheets, with students in the diagram+verbal group receiving two pages. Each synthesizer was prefaced with instructions explaining its use, and the time allowed for its study. The diagram synthesizer is shown in Figure 3, the verbal synthesizer is shown in Figure 4, and the combined diagram+verbal version is shown in Figure 5. The instructions for the diagram+verbal synthesizer were slightly shortened versions of the instructions for the diagram and

Verbal Synthesizer	Diagram Synthesizer: Absence	Diagram Synthesizer: Presence
Absence	No Synthesis	Diagram Synthesizer
Presence	Verbal Synthesizer	Diagram+Verbal Synthesizer

Figure 1. Statistical Design

Script	Slide
....	
A microcomputer is an information-processing system.	Microcomputer system
You put information in, do something with it such as combine it, reformat it or classify it, and get processed information out.	Words
For example, if you have to do a report for your English class, you could type the information into the microcomputer, the microcomputer would put it in nice, neat paragraphs, check the spelling and print it so that it looks something like this.	Printout
What is a microcomputer system?	Blank
That's right, it is an information-processing system.	Microcomputer/Words
What does a microcomputer system allow you to do?	Blank
You should have said put information in, do something with it and get processed information out.	Words
.....	

Figure 2. Excerpt from Instructional Material (Script of Slide-Tape)

INSTRUCTIONS: The following is a tree-chart to help you synthesize what you have just learned. The chart begins with the top box and goes down in the same order that you viewed the slides. A higher level box that branches down into more boxes indicates that the higher box has those lower boxes as parts.

Look at the chart several times and try to remember the relationship of all the parts by starting with the top box and going downward. You have about five minutes to study this chart. Then it will be collected and you will be given the test.

TREE-CHART OF THE MICROCOMPUTER SYSTEM

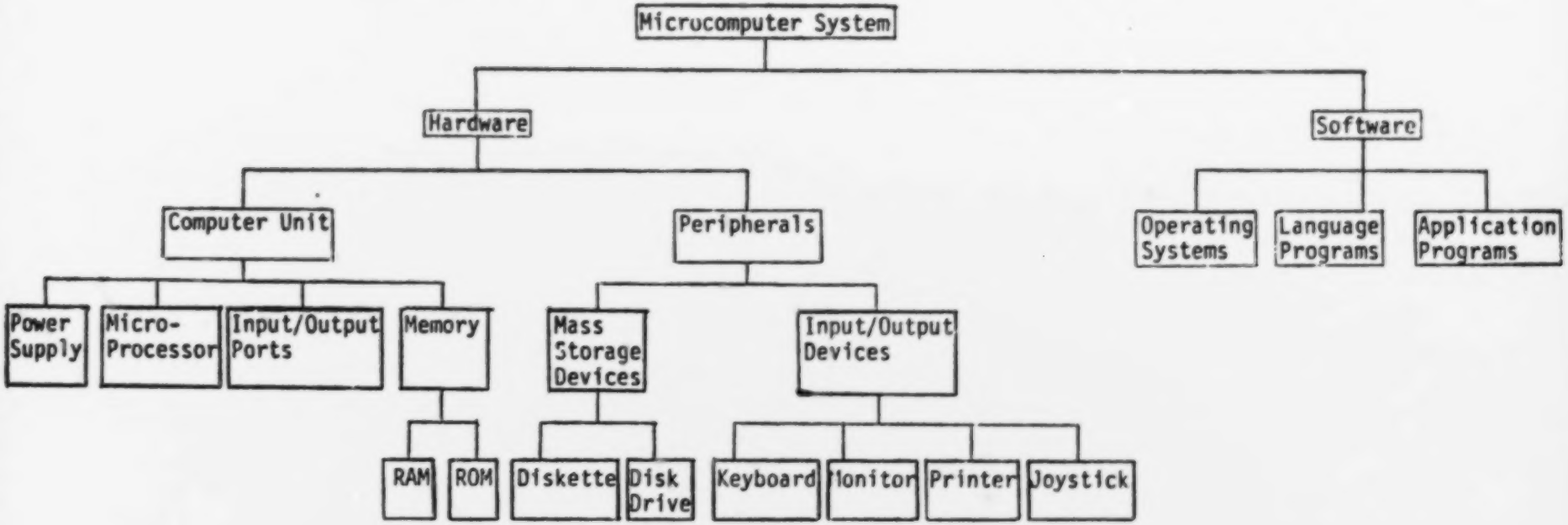

Figure 3. Diagram Synthesizer

verbal synthesizers, in order to balance the time needed to study the additional material.

Insert Figures 4 and 5 about here

Tests and Measures

All students received the same posttest, which consisted of 26 short-answer questions. The test had a total of 41 possible correct answers with items testing both definitions and relationships of the microcomputer system parts. The test items were subjectively sequenced in a random order. Instructions preceding the test directed the students to write in their names and then explained the administration procedures. The tests were clear photocopies of typewriter-produced originals on 8.5x11 inch paper. Instructions for the test were written so as to require no additional oral explanations. See Figure 6 for a sample of test items.

Insert Figure 6 about here

Procedures

The research was carried out in three consecutive class periods on April 4, 1983. The procedures were repeated three times for the three separate, intact class sections. In each section, students entered the room in their own order, and were immediately given a card with the random number from 1 to 5 and seated in rows according to group number. Rows were arranged in groups numbered 1-4 prior to class. Students in the control group were taken to a study hall and were supervised while they completed the posttest booklet. Students in the four treatment groups then viewed the slide-tape presentation at the same time. Depending on the assigned treatment, they were then given either a synthesizer or the test. Students in the three synthesizer groups were given approximately 5 minutes to study the synthesizers before they were collected and then were given the test. The synthesizer and test were not presented together to the students in order to prevent them from returning to look at the synthesizer during the test. Figure 7 shows the total path for each group. All students were given adequate time to complete the test (approximately 15 minutes).

Insert Figure 7 about here

INSTRUCTIONS: The following are some statements to help you synthesize what you have just learned. The statements follow the same order that you viewed the slides.

Read the statements several times and try to remember the relationship of all the parts. You have about five minutes to study these statements. Then it will be collected and you will be given the test.

STATEMENTS OF THE MICROCOMPUTER SYSTEM

The microcomputer system has two main parts, the hardware and the software.

The hardware includes the computer unit and the peripherals.

The computer unit includes the power supply, microprocessor, input/output ports, and a memory.

There are two parts of memory, RAM and ROM.

Peripherals include the mass storage devices and input/output devices.

The parts of a mass storage device are the diskette and the disk drive.

Input/output devices include the keyboard, monitor, printer, and joystick.

Software can be operating systems, language programs, or application programs.

Figure 4. Verbal Synthesizer

INSTRUCTIONS: The following are 2 pages of information to help you synthesize what you have just learned.

This page contains a tree-chart which begins with the top box and goes down in the same order that you viewed the slides. A higher level box that branches down into more boxes indicates that the higher box has those lower boxes as parts.

Look at the chart several times and try to remember the relationship of all the parts by starting with the top box and going downward. Then go to the next page. You are allowed to flip pages and have altogether about five minutes. Then both sheets will be collected and you will be given the test.

TREE-CHART OF THE MICROCOMPUTER SYSTEM

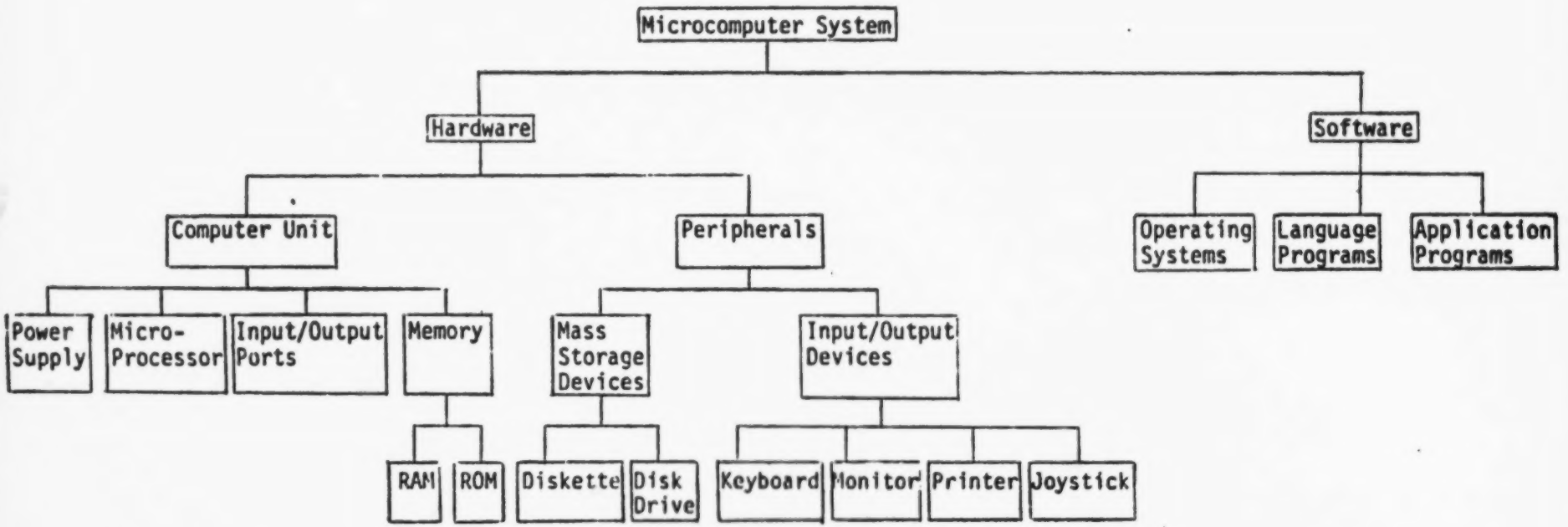

Figure 5. Diagram + Verbal Synthesizer

INSTRUCTIONS: This page contains statements to help you synthesize what you have just learned. Read the sentences several times and try to remember the relationship of all the parts.

STATEMENTS OF THE MICROCOMPUTER SYSTEM

The microcomputer system has two main parts, the hardware and the software.

The hardware includes the computer unit and the peripherals.

The computer unit includes the power supply, microprocessor, input/output ports, and a memory.

There are two parts of memory, RAM and ROM.

Peripherals include the mass storage devices and input/output devices.

The parts of a mass storage device are the diskette and the disk drive.

Input/output devices include the keyboard, monitor, printer, and joystick.

Software can be operating systems, language programs, or application programs.

Figure 5. Diagram + Verbal Synthesizer

1. What is hardware?*

_____

_____

2. What is the function of the memory?*

_____

_____

....

5. What are the two parts of the mass storage devices?+

a) _____

b) _____

....

7. What are the 3 software parts?+

a) _____

b) _____

Figure 6. Excerpt from Test Booklet

* Definition items.

+ Relationship items.

Treatment Groups	With Synthesizer	View Slides -- Study Synthesizer -- Take Test
	No Synthesis	View Slides -- Take Test
Control	No instruction	Take Test

Figure 7. Tasks for Students in Different Experimental Groups

Results

As expected, results of a one-way ANOVA indicate that the students had little prior knowledge of the instructional content, because the control group (which received no instruction) performed significantly worse than all other groups on the total test ($p=.0021$), as well as on relationship items alone ($p=.0001$) and definition items alone ($p=.049$). The mean scores of the four treatment groups obtained on the total test, definition items and relationship items are shown in Table 1.

Insert Table 1 about here

To our surprise, the two-way ANOVA showed no significant differences for either the total score or the definition score (see Tables 2). There was a main effect, however, for the diagram synthesizer on relationship items (see Table 2c). The presence of the diagram synthesizer significantly improved performance on relationship items ($p=.0038$).

Insert Table 2 about here

A Duncan's multiple range test on relationship scores (see Table 3) revealed that the diagram synthesizer was not significantly different than the diagram+verbal synthesizer. The diagram synthesizer was significantly better than the verbal synthesizer and no synthesis ($p=.05$), while the diagram+verbal synthesizer was significantly better than no synthesis.

Insert Table 3 about here

Discussion

Hypothesis 1 stated that results with a verbal synthesizer would equal results with a diagram synthesizer (diagram = verbal). This hypothesis was only partially supported. It was supported by results on the total score and definition items; but on relationship items, the diagram synthesizer was significantly better than the verbal synthesizer (diagram > verbal). Synthesizers only provide instruction on relationships. Our initial hypotheses did not anticipate the finding that a diagram synthesizer provides a clearer and more lasting synthesis than does a verbal synthesizer. It seems that a carefully prepared diagram helps learners understand conceptual relationships better than printed words.

Hypothesis 2 stated that a diagram+verbal synthesizer would be superior to either the diagram or the verbal synthesizer alone (diagram+verbal diagram = verbal). The hypothesis was not supported for either

Table 1
Mean Scores of Correct Responses of the Four Treatment Groups on the Total Test (41 possible correct) Definition Items (24 possible correct) & Relationship Items (17 possible correct)

(parentheses indicate percentage)

Verbal Synthesizer	Diagram Synthesizer: Absent			Diagram Synthesizer: Present			Main Effect: Verbal Absent		
	No Synthesis			Diagram Synthesizer			Verbal Absent		
	Total Test	Definitions	Relationships	Total Test	Definitions	Relationships	Total	Def.	Rel.
Absent	11.50 (28.50%) sd=5.10 n=10	9.30 (38.75%) sd=3.59 n=10	2.20 (12.94%) sd=1.19 n=10	16.86 (41.11%) sd=8.99 n=7	9.14 (38.10%) sd=5.34 n=7	7.71 (45.38%) sd=5.25 n=7	14.18	9.22	4.96
	Verbal Synthesizer			Diagram+Verbal Synthesizer			Verbal Present		
	Total Test	Definitions	Relationships	Total Test	Definitions	Relationships	Total	Def.	Rel.
Present	13.70 (33.41%) sd=5.96 n=10	9.50 (39.58%) sd=4.55 n=10	4.20 (24.71%) sd=2.15 n=10	14.33 (34.96%) sd=7.19 n=9	8.00 (33.33%) sd=3.43 n=9	6.33 (37.25%) sd=4.74 n=9	14.02	8.75	5.27
Main Effect	Diagram Absent			Diagram Present					
	Total Test	Definitions	Relationships	Total Test	Definitions	Relationships			
	12.16	9.40	3.20	15.60	8.57	7.02			

Control		
Total Test	Definitions	Relationships
5.36 (13.08%) sd=2.54 n=11	5.00 (20.83%) sd=1.61 n=11	0.36 (2.12%) sd=1.21 n=11

Table 2
Two-Way ANOVA Table

a. On the Total Test

Source	Sum of Squares	df	F	PR F
Diagram	79.05	1	1.74	0.20
Verbal	0.23	1	0.01	0.94
Diagram+Verbal	49.15	1	1.08	0.31
Error	1453.46	32		

b. On the Definition Test Items

Source	Sum of Squares	df	F	PR F
Diagram	6.05	1	0.34	0.56
Verbal	1.96	1	0.11	0.74
Diagram+Verbal	3.97	1	0.11	0.64
Error	567.46	32		

c. On the Relationship Test Items

Source	Sum of Squares	df	F	PR F
Diagram	128.83	1	9.75	0.0038
Verbal	0.84	1	0.06	0.80
Diagram+Verbal	25.18	1	1.91	0.18
Error	422.63	32		

Table 3
Duncan's Multiple Range Test for Relationship Items

Diagram Synthesizer	Diagram+Verbal Synthesizer	Verbal Synthesizer	No Synthesis
mean=7.71	mean=6.33	mean=4.20	mean=2.20

Note: 1) Alpha=0.05 df=42 MSE=10.4089
2) Harmonic Mean of Cell Sizes=9.17638
3) Means linked by a continuous underscore are not significantly different.

definition items or for the relationship items. For the definition items, there were no significant differences whatsoever. For the relationship items, the diagram+verbal group was not significantly different from either format of synthesis alone, and the insignificant difference with the diagram synthesizer was in the wrong direction. Initially, we had felt that the combined format would accommodate individual differences in learning preferences better than either used alone and hence would provide the students with the strengths of both the diagram and the verbal synthesizers. But our results indicate that the combined synthesizer was not more effective than the diagram synthesizer alone. Since time to study the synthesizers was equal for all groups, it can be inferred that students in the combined-version group spent less time studying the diagram portion of the synthesizer. Thus this finding strengthens the conclusion from the results for Hypothesis 1 that visual synthesis is more effective than verbal synthesis.

Hypothesis 3 stated that instruction followed by synthesis would be superior to instruction without synthesis (diagram, verbal, diagram+verbal > no synthesis). This hypothesis was only supported for the diagram and the diagram+verbal synthesizers on relationship items. There was no significant difference between verbal and no synthesis on relationships, and no differences at all on definition items. The instructional materials in our study followed the elaboration theory (Reigeluth & Stein, 1983) but were prepared with great care to insure that neither summarizers (i.e. reviews) nor synthesizers existed in the slide-tape presentation. Since synthesizers only focused on conceptual relationships, the fact that the means of all groups (including the no synthesis group) were similar on definition items indicates that knowledge of relationships does not facilitate recall of definitions, which implies that they do not influence the meaningful assimilation of the individual concepts.

To sum up, we found no significance between the treatment groups on remembering definitions. But on remembering relationships, the diagram synthesizer was significantly better than verbal and no synthesis, while the diagram+ verbal synthesizer was only significantly better than no synthesis. In other words, this study indicates that relationships should only be taught if students are to learn those relationships, and that relationships should be taught in a visual format only.

In this study, an attempt was made to modify the procedures of the Frey and Reigeluth (1981) study by keeping time to study the synthesizer and perform the instructional task constant among groups, as well as by providing instructions for use of the synthesizer. Carson and Reigeluth (1983) found no significant difference in results for presence of synthesis, even by making these same modifications. The different findings in our study may have come from the fact that the students were older and may have been more familiar with tree-chart diagrams.

The studies of Frey and Reigeluth (1981) and Carson and Reigeluth (1983) both indicate that synthesis is most effective when provided at the end of a general-to-detailed conceptual lesson. This finding is supported by our study, which used a general-to-detailed sequence with synthesis at the end.

The results of our study, however, contradict the proposition by Frey & Reigeluth (1981) that synthesis may not be very effective for small units of instruction. Even with the instruction lasting only 16 minutes in our study, the visual synthesizer (a tree-chart diagram in our case) was significantly better than no synthesizer for conceptual relationships. The different findings may have resulted from the fact that we provided instructions on the use of the synthesizers while they did not.

Carson & Reigeluth (1983) also suggest that 19 subordinate concepts in one diagram synthesizer may have been too many (for eighth graders) to detect the true power of the synthesizer. But the same type of synthesizer in the present study using 21 subordinate concepts with students in grades 10-12 was significantly better not only than no synthesis but also than the verbal synthesizer. It may thus be inferred that the power of a diagram synthesizer depends heavily on prior development of the students' ability to comprehend and use it.

As definitions and relationships do not seem to be closely related, our study lends support to the elaboration theory that synthesis can greatly improve learning of conceptual relationships. Further, we conclude that a visual synthesizer is more effective than a verbal synthesizer. We believe that these conclusions can be generalized to high school students of average ability, and to conceptual instruction in general. Possible limitations to generalizability of this study include:

1. only high school students or above,
2. only conceptual relationships, and
3. only a tree-chart diagram to represent visual synthesizers.

Thus more research with different samples is needed to find out if similar results can be obtained for other age groups using other formats of visual synthesizers for teaching other kinds of relationships, for example, using flow-charts as visual synthesizers for order relationships. More research may also be needed to test whether synthesis is particularly useful for short instructional units and whether the same formats of synthesizers demonstrate the same degree of effectiveness across different age groups/backgrounds.

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